The Effects of Joint Mobility and Stability on Pain Levels in Division Ⅰ Collegiate Gymnasts

An Honors Thesis (HONR 499)

By

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Abstract:

There are varied reports in the literature linking joint movement dysfunction or imbalances and overuse injuries from repeated sport participation over a prolonged period of time. The purpose of this study was to determine if there was a correlation between mobility and stability of collegiate gymnasts and their pain ratings during a competitive season. The study was conducted with 19 female collegiate gymnasts. Prior to the beginning of the competitive gymnastics season, each participant completed a pre-test that included four out of seven Functional Movement Screen (FMS) assessments as well as the Thomas Test. During the competitive season, each subject rated their pain over the course of 10 weeks. At the end of the gymnastics season, the same assessments were then completed as the post-test. Average FMS scores as well as Thomas Test pass or fail ratings were compared to average pain data to determine that there was a significant correlation between the post-test FMS scores and the overall average pain data. No other significant correlations were found. Overall, while some trends were found between some FMS scores, Thomas Test scores, and the pain data, there was only a significant correlation between the post-test FMS scores and the overall average pain.

Acknowledgments:

I would like to thank Ms. Mary Winfrey Kovell for all of her help, advice, and patience during this project. This project would not have been possible without her guidance and support.

I would also like to thank the gymnastics team at Ball State University for allowing me to conduct my experiment with their team and their willingness to help me accomplish my goals.

Process Analysis Statement:

There was a great deal of planning and preparation that went into making this study a success. In the beginning stages, I spent time talking with my advisor about what the study would focus on and the best way for me to incorporate both my education in exercise science as well as my love for gymnastics. Once the basic idea was set, I then moved into planning the timeline for the study as well as talking to the gymnastics coach to see if it would even be possible for me to work with the team. The next big step was gaining approval from the IRB so that I would be allowed to work with human subjects. This process involved writing a detailed proposal that included all of the details of the study. This not only included the proposal but also the consent forms, survey questions, and recruitment information. After three rounds of revisions, I was finally approved by the IRB to start my study.

I then set a date to talk to the gymnastics team and ask for volunteers to participate in my study. Once I had all of my participants, I set up times with the gymnastics coach where I would be able to come in and complete my pre-test with the subjects. This took about 10 minutes for each of my 19 subjects. After several days of conducting the pre-test, I was able to complete the pre-test for all of the subjects. This then began the process of data collection. Over the course of the 10 week competitive season, surveys were completed twice a week after practice on the day of data collection. Each data collection day the surveys were sent out via email and I attended the last 10 minutes of the teams practice to remind the participants to complete the study on their way out of practice. At the end of the day, I would review the information from each online survey and transfer the information to a spreadsheet for organizational purposes. After 10 weeks, the competitive season was over and it was now time to complete the post-test. I was able to complete all post-test evaluations during two separate practices. I then reviewed all pre and post-test information and transferred it to a spreadsheet for organization.

While this concluded the study portion of my thesis, my work was far from over. I then met with a statistician who helped me to review my data as well as ran statistical tests to determine if any correlations existed within the data. Over the course of a meeting and several phone calls, the statistician was able to explain all correlations in the data as well as assist me in composing charts and figures for my paper.

I feel that this project has been a wonderful learning experience for me. I was able to apply my educational experiences such as working with the Functional Movement Screen and the Thomas Test as well as improve my analytical and writing abilities. It has helped me to become a more informed student and has improved my ability to be self motivated. I have spent the last year working on this project and I am so proud of what it has become and the type of student it has pushed me to be.

Introduction:

Overuse injuries are one of the most common injuries that year-long participation athletes, such as gymnasts face during their sport participation. An overuse injury can be defined as cumulative micro-injuries that result from repeated impact over a prolonged period of time (Hamill, Palmer, Van Emmerik, 2012). Additionally, this repetitive stress does not give the body proper time to heal in response to the micro-injuries experienced during training which results in an overuse injury (Brenner, 2007). Overuse injuries can have a variety of different causes such as inadequate rest, overtraining, and muscle weakness or imbalance (“The risk of overuse injuries”, 2016). As these injuries have become more common, exercise professionals have implemented assessments to identify movement imbalances and muscle weakness that are common causes of pain and overuse.

A widely utilized movement screen is the Gray-Cook Functional Movement Screen or FMS. This assessment is intended to assess functional movement patterns and performance (Cook, Burton, Hoogenboom, Voight, 2014). The FMS is made up of seven individual assessments scored on a scale of 0-3 based on the subject’s ability to complete the movement pattern with or without compensation. The seven assessments are the deep squat, shoulder mobility, hurdle step, in-line lunge, active straight leg raise, rotary stability, and trunk stability push-up.

The FMS is a unique assessment that puts the body into specific positions so dysfunction is easy to observe at the spine, shoulder, hip, knee, and ankle. In these positions, if the subject has muscle weakness or imbalance at a joint it becomes apparent during the assessment and the information is used to create an exercise prescription (Cook, Burton, Hoogenboom, Voight, 2014). These weaknesses or imbalances need to be identified quickly to prevent the development of compensatory movement patterns that put athletes at an increased risk for injury (Lloyd, Oliver, Radnor, Rhodes, Faigenbaum, & Myer, 2015). Compensatory patterns are typically responsible for an athlete's first step toward an overuse injury which can lead to pain during activity (Brenner, 2007). The development of pain can impact an athlete's performance and even persist during rest (Brenner, 2007).

Another industry standard assessment for joint dysfunction is the Thomas Test. This test assesses the flexibility of the hip flexors as well as the rectus femoris and iliotibial band (IT band). Similar to the FMS, lack of mobility in these areas can lead to compensatory patterns that put athletes at an increased risk for injury. Restricted hip mobility may lead to low back pain or increased impact during running that can affect athletic performance (Vigotsky, Lehman, Beardsley, Contreras, Chung, & Feser, 2016).

When deciding which tests would be most beneficial in determining mobility, four out of the seven FMS tests were chosen as well as the Thomas Test. The four FMS assessments that were chosen were the deep squat, shoulder mobility, rotary stability, and trunk stability push-up. The deep squat was chosen because of its focus on functional hip mobility and ankle mobility as well as secondary assessment of shoulder flexion and core stability. The shoulder mobility test was chosen to assess the ability of the subject to both internally and externally rotate at the shoulder. The rotary stability and trunk stability push-up tests were chosen for their focus on core stability and motor control. The Thomas Test was chosen for its ability to assess multiple areas of hip mobility. This test looks at not only the flexibility of the hip flexors, but also the rectus femoris and IT band. These three areas greatly contribute to how the hip moves which can be a big factor in developing movement patterns. Because gymnastics utilizes all parts of the body during practice and competition, these movement patterns are extremely important. If an athlete has limitations in any of these areas it can cause the development of compensatory movement patterns that can then lead to pain and overuse injuries (Lloyd et al., 2015).

These movement patterns can be exaggerated during sports such as gymnastics that experience high impact during jumping and landing. It has been shown that gymnasts are most at risk for injury during landings (Wade, Campbell, Smith, Norcott, & O'sullivan, 2012). Gymnasts also experience up to 13 times their body weight in ground reaction force during landing (Wade et al., 2012). It can easily be seen that if a gymnast is experiencing forces up to 13 times their body weight in a compensatory body position that they would be at significant risk for injury resulting in pain.

When deciding which areas should be assessed for pain, it was determined that the most common areas for injury in gymnastics should be used. Research in the field shows that the most common areas for injury in gymnasts are the ankle, knee, hip, back, and shoulders (Kerr et al., 2015). According to a ten year observational study of collegiate gymnasts, the ankle or foot is the most common area for injury in gymnastics.

This was followed by the knee, shoulder, hip, and back in that order (Westermann et al., 2015).

The purpose of this study is to examine the relationship between mobility and pain levels in Division Ⅰ collegiate gymnasts. The author hypothesized there would be a correlation between low scores on the four FMS assessments and the Thomas Test and high pain rankings for 5 areas of the body.

Methods:

Subjects:

A total of 19 female subjects between the ages of 18 and 23 were selected as a result of their participation on a Division Ⅰ collegiate gymnastics team at Ball State University. All team members were given the opportunity to voluntarily participate. Prior to the start of the study, each participant signed a consent waiver explaining the details of the study. The study gained approval from the Institutional Review Board (IRB) to allow the use of human subjects.

Procedures:

This study was conducted in three phases. The pre-test, data collection, and post-test phase.

Pre-Test:

The pre-test consisted of completing four out of the seven assessments from the FMS as well as the Thomas Test to assess mobility restrictions. The FMS deep squat, shoulder mobility, rotary stability, and trunk stability push-up assessments were used which can be seen in figure 1 below. Each of the four FMS assessments were scored on a scale of 0-3. A score of 3 indicates that the subject completed the movement perfectly without any movement restriction according to the standards set by the FMS (Functional Movement Systems, 2010). A score of 2 indicates that the subject completed the movement with compensation and limited or no movement restrictions. A score of 1 indicates that the subject cannot complete the movement with compensation and displays gross movement restrictions. Lastly, a score of 0 indicates that the subject experienced pain with the desired movement.

The Thomas Test was scored on a pass or fail basis which can be seen in figure 2 (Vigotsky, Lehman, Beardsley, Contreras, Chung, & Feser, 2016). The researcher observed the subjects leg position during the desired movement and scored the test according to the guidelines of the Thomas Test. The pre-test was completed before the start of the team's competition season and was completed for each subject participating in the study.

Figure 1: FMS Assessments

<u>*Deep Squat:*</u> The purpose of the deep squat is to assess bilateral, symmetrical and functional mobility of the hips, knees, ankles, and restrictions of the spine and shoulders. Typical restrictions are ankle dorsiflexion, hip flexion, shoulder external rotation and flexion, and spine extension. A score of 3 indicates no restrictions. A score

of 2 indicates restriction of ankle dorsiflexion. A score of 1 indicates gross restrictions of ankle, hip, shoulder, and/or spine.

Shoulder Mobility: The purpose of the shoulder mobility is to assess fundamental mobility of bilateral shoulder range of motion, combining internal rotation with adduction and external rotation with abduction. A score of 3 indicates no shoulder restrictions. A score of 2 indicates limited shoulder mobility. A score of 1 indicates gross restriction of shoulder mobility.

Rotary Stability: The purpose of the rotary stability is to assess functional core stability in bilateral, multi-plane trunk stability during a combined upper and lower extremity motion. Typical restrictions are core strength, hip flexion, and spine flexion. A score of 3 indicates no restrictions. A score of 2 indicates moderate asymmetrical core strength. A score of 1 indicates gross lack of core strength, hip flexion, and/or spine flexion.

Trunk Stability Push-up: The purpose of the trunk stability push-up is to assess functional core strength or the ability to stabilize in the sagittal plane while performing a symmetrical upper-extremity shoulder motion. Typical restrictions are core strength and upper extremity strength. A score of 3 indicates no restrictions. A score of two indicates limited core and upper extremity strength. A score of 1 indicates significant lack of core and upper extremity strength.

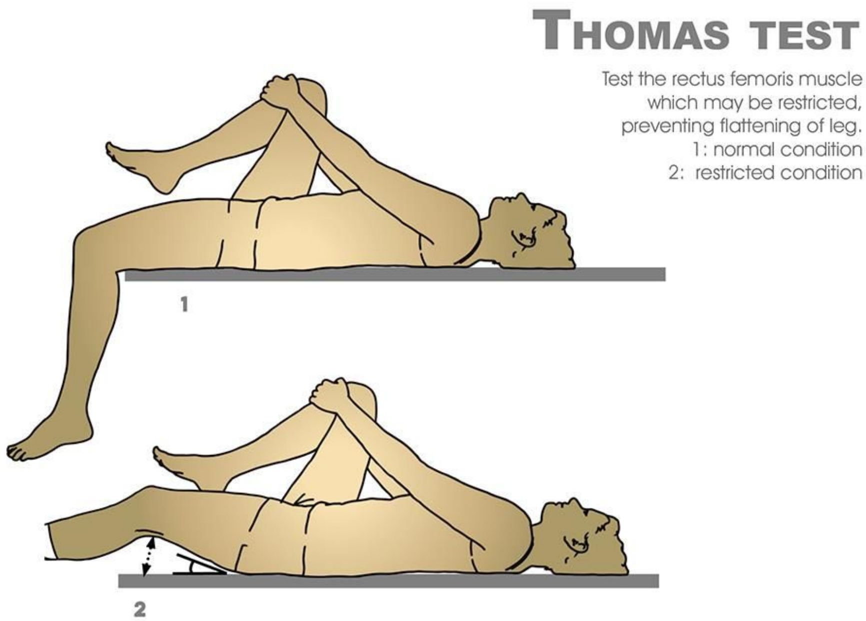

Figure 2: Thomas Test

Thomas Test: During the Thomas Test, the researcher assessed three different areas of the hip, the hip flexors, iliotibial band (IT band), and rectus femoris. The score is determined by the position of the subject's leg in relation to specific anatomical landmarks of the leg. The test was scored on a pass or fail basis in each of the three areas being measured. Failure of the hip flexor assessment indicates tight or shortened hip flexors. Failure of the rectus femoris assessment indicates tight or shortened rectus femoris. Failure of the IT band assessment indicates tight or shortened IT band.

Data Collection:

Data collection occurred for 10 weeks during the competitive gymnastics season. During data collection, each subject was asked to rate their pain level on a scale of 0-10 in five different areas of the body. This data was collected through an online survey that was emailed to the subjects two times per week for 10 weeks. In order to keep the data from the surveys confidential, each subject was also given a participation number that they were asked to enter on the survey each time they completed it. The survey asked the subjects to rate their pain level for that day in their shoulders, back, hips, knees, and ankles. The collected data was added to an excel document for organization purposes.

Post-Test:

During the post-test portion of this study, the same four assessments from the FMS as well as the Thomas Test were completed with the same procedures as the pre-test. The scores were recorded for correlation to pre-test scores.

Results:

The correlation between the FMS post-test scores and average pain was found to be significant at the 0.01 level. Average pain was also found to be significantly correlated to the change in FMS score at the 0.05 level. Additionally, the scores for the pre-FMS test and the post-FMS test were found to be significantly correlated. The Thomas Test scores were found to not be significantly correlated to the average pain score. Average total pain was reported as 2.04 ± 0.38 on a scale of 0-10.

Table 1: Average Scores for pre-FMS and post-FMS

Test	Mean
Pre deep squat	1.31 ± 0.480
Pre shoulder mobility	2.00 ± 0.816
Pre rotary stability	1.54 ± 0.519
Pre trunk stability push-up	2.85 ± 0.376
Pre total FMS score	7.69 ± 1.38
Post deep squat	1.46 ± 0.519
Post shoulder mobility	1.69 ± 0.855
Post rotary stability	1.62 ± 0.506
Post trunk stability push-up	2.77 ± 0.439
Post total FMS score	7.54 ± 1.56

Table 2: Thomas Test frequency of pass or fail: Right leg

	Pass	Fail
Pre right hip flexor	13	0
Pre right rectus femoris	2	11
Pre right IT band	3	10
Post right hip flexor	12	1
Post right rectus femoris	2	11
Post right IT band	1	12

Table 3: Thomas Test frequency of pass or fail: Left leg

	Pass	Fail
Pre left hip flexor	13	0
Pre left rectus femoris	2	11
Pre left IT band	0	13
Post left hip flexor	12	1
Post left rectus femoris	3	10
Post left IT band	0	13

Table 4: Average pain data

Area	Mean	Standard Deviation
Shoulder	1.77/10	± 1.56
Back	2.78/10	± 2.04
Hip	1.3/10	± 1.10
Knee	1.57/10	± 1.88
Ankle	3.12/10	± 2.84

Table 5: Correlations between FMS scores and average overall pain

Spearman's Rho

	Pre FMS score	Post FMS score	Change in FMS score	Average overall pain
Pre FMS score	1.00	0.61*	-0.29	0.14
Post FMS score	0.61*	1.00	0.55	0.69**
Change in FMS score	-0.29	0.55	1.00	0.61*
Average overall pain	0.14	0.69**	0.61*	1.00

* correlation is significant at the 0.05 level (2-tailed)

**correlation is significant at the 0.01 level (2-tailed)

Table 6: Correlation between Thomas Test (right leg) and average overall pain

Spearman's Rho

	Pre Thomas Test right	Post Thomas Test right	Change in Thomas Test right	Average overall pain
Pre Thomas Test right	1.00	0.48	-0.64*	0.16
Post Thomas Test right	0.48	1.00	0.32	0.39
Change in Thomas Test right	-0.64*	0.32	1.00	0.15
Average overall pain	0.16	0.39	0.15	1.00

*correlation significant at the 0.05 level (2-tailed)

Table 7: Correlation between Thomas Test (left leg) and average overall pain

Spearman's Rho

	Pre Thomas Test left	Post Thomas Test left	Change in Thomas Test left	Average overall pain
Pre Thomas Test left	1.00	0.70**	0.00	-0.17
Post Thomas Test left	0.70**	1.00	0.71**	-0.02
Change in Thomas Test left	0.00	0.71**	1.00	0.16
Average overall pain	-0.17	-0.02	0.16	1.00

**correlation significant at the 0.01 level (2-tailed)

Discussion:

The purpose of this study was to identify a relationship between mobility in Division I gymnasts and their pain ratings during a competitive season. It was hypothesized that there would be a correlation between lower mobility scores and higher pain rankings. Overall, it was thought that scores on mobility tests such as the FMS and Thomas Test would be good predictors of pain in athletes, specifically gymnasts. The FMS and Thomas Test were used to assess the mobility and stability of 19 female gymnasts. The results showed there to be a correlation between the post-test FMS scores and the average overall pain reported by the subjects. Additionally, the results showed there to be no correlation between the pass or fail of the Thomas Test and the average overall pain ratings. The hypothesis was partially supported by the results of this study through the correlation between the pain ratings and FMS scores during the post-test but was not supported by the results of the Thomas Test or pre-test scores for the FMS.

While there was not a statistical correlation between the pass or fail of the Thomas Test and pain levels, it should be noted that there was a common trend of failure in the areas of rectus femoris and IT band on both the right and left leg during both the pre and post-test. Tightness in these areas could affect the body's ability to efficiently move and decelerate during landing, which could lead to pain in the back, knees, or ankles. The data reflects a possible trend in this area seeing as almost all subjects received a failing result in both the rectus femoris and IT band indicating tightness, and the average pain values were at their highest in the back and ankle area. The knee was recorded as the fourth highest area of pain following the shoulder, but was still recorded as a higher average pain rating than the hip.

Another trend that should be noted is the consistently low scores on the FMS deep squat assessment. Low scores on this assessment is an indicator for poor movement patterns during squatting which can be easily translated to landing or jumping. Because gymnasts land with high impact in an extended overhead position, poor squat mechanics can be a good predictor of poor landing or jumping mechanics. This can put extra stress on areas such as the lower back, knees, and ankles which was reflected in the data with the back and ankles being the highest rated areas of pain. It could then be hypothesized that low scores on the FMS deep squat assessment could be a good predictor of back, knee, or ankle pain.

The FMS scores also showed consistently low scores on the rotary stability assessment. Low scores on this assessment is an indicator for poor core stability or asymmetrical trunk stability between the left and right side. This translates to gymnastics in the form of rolling or twisting. If gymnasts lack the basic core control for the rotary stability assessment it could lead to pain with rotational motions that are very common in gymnastics (Tilley, 2018).

This study was limited by the number of athletes participating in this study. The smaller sample size made it difficult to determine if a relationship truly exists. While there was found to be a correlation between the average overall pain with the post-test FMS score, it is possible that there are more correlations that are not clear due to the small sample size. It was also limited by the subjects recall of their pain while answering the survey questions. While the subjects were instructed to complete the survey immediately following practice, some subjects waited to complete the survey which means that their pain ratings were based on what they recall from that practice. The pain data is also affected by each subject's interpretation of pain. Each subject has a different tolerance for pain and chose their pain ratings accordingly.

Conclusion:

The results of this study suggest there is a correlation between the post-test FMS scores and the average overall pain reported by the subjects. Although other correlations were not found, trends were identified between specific high pain ratings and specific assessments on the FMS and Thomas Tests. To improve this study, researchers should consider adjusting the pain rating scale from 0-10 to 0-5. This would allow for less variation of the pain ratings and would provide more accurate data to assess for correlations.

It may also be beneficial to investigate the implementation of corrective exercises based on the subject's mobility and stability limitations to see if reported pain would decrease with corrections to movement patterns. Additional recommendations would be to analyze the subject's landing mechanics for error and compensation to provide more detailed information about landing compensations that might be related to pain. This could be completed not only in a basic landing such as jumping, but also during tumbling landings which would be more specific to gymnasts. A larger sample size would be recommended to see if other correlations arose within the data resulting from more subject participation.

If implemented correctly, the results of this study suggest the FMS and other movement screens could be a great benefit to athletes and coaches by identifying mobility issues to prevent injury which could improve overall athletic performance.

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Office of Research Integrity
Institutional Review Board (IRB)
2000 University Avenue
Muncie, IN 47306-0155
Phone: 765-285-5070

DATE:	December 19, 2018
TO:	Haley Wiley
FROM:	Ball State University IRB
RE:	IRB protocol # 1354832-1
TITLE:	The Effects of Joint Mobility and Stability on Pain Levels in Division 1 Collegiate Gymnasts
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
DECISION DATE:	December 19, 2018
EXPIRATION DATE:	
REVIEW TYPE:	**Expedited:** This protocol had been determined by the board to meet the definition of minimal risk.

The Institutional Review Board has approved your New Project for the above protocol, effective December 19, 2018 through . All research under this protocol must be conducted in accordance with the approved submission and in accordance with the principles of the Belmont Report.

Review Type:

	Category 1: Clinical studies of drugs and medical devices
	Category 2: Collection of blood samples by Finger stick, Heel stick, Ear stick, or Venipuncture
	Category 3: Prospective collection of biological specimens for research purposes by noninvasive means
X	**Category 4:** Collection of data through Non-Invasive Procedures Routinely Employed in Clinical Practice, excluding procedures involving Material (Data, Documents, Records, or Specimens) that have been collected, or will be collected solely for non-research purposes (such as medical treatment or diagnosis)
	Category 5: Research involving materials that have been collected or will be collected solely for non-research purposes.
	Category 6: Collection of Data from Voice, Video, Digital, or Image Recordings Made for Research Purposes

	Category 7: Research on Individual or Group Characteristics or Behavior or Research Employing Survey, Interview Oral History, Focus Group, Program Evaluation, Human Factors, Evaluation, or Quality Assurance Methodologies
	Category 8: Continuing review of research previously approved by the convened IRB
	Category 9: Continuing review of research, not conducted under an investigational new drug application or investigational device exemption where categories 2-8 do not apply but the IRB has determined and documented at a convened meeting that the research involves no greater than minimal risk and not additional risks have been identified.

As a reminder, it is the responsibility of the P.I. and/or faculty sponsor to inform the IRB in a timely manner:

- when the project is completed,
- if the project is to be continued beyond the approved end date,
- if the project is to be modified,
- if the project encounters problems, or
- if the project is discontinued.

Any of the above notifications must be addressed in writing and submitted electronically to the IRB (http://www.bsu.edu/irb). Please reference the IRB protocol number given above in any communication to the IRB regarding this project. Be sure to allow sufficient time for review and approval of requests for modification or continuation. If you have questions, please contact Grace Yoder at (765) 285-5034 or gmyoder@bsu.edu.

In the case of an adverse event and/or unanticipated problem, you will need to submit written documentation of the event to IRBNet under this protocol number and you will need to directly notify the Office of Research Integrity (http://www.bsu.edu/irb) **within 5 business days**. If you have questions, please contact (ORI Staff).

Please note that all research records must be retained for a minimum of three years after the completion of the project or as required under Federal and/or State regulations (ex. HIPAA, FERPA, etc.). Additional requirements may apply.

D. Clark Dickin, PhD/Chair
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Christopher Mangelli, JD, MS, MEd, CIP/
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